(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 134 413 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
19.09.2001 Bulletin 2001/38

(51) Int Cl.^{7}: **F04B 27/10**

(21) Application number: **01106655.2**

(22) Date of filing: **16.03.2001**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **17.03.2000 JP 2000075537**

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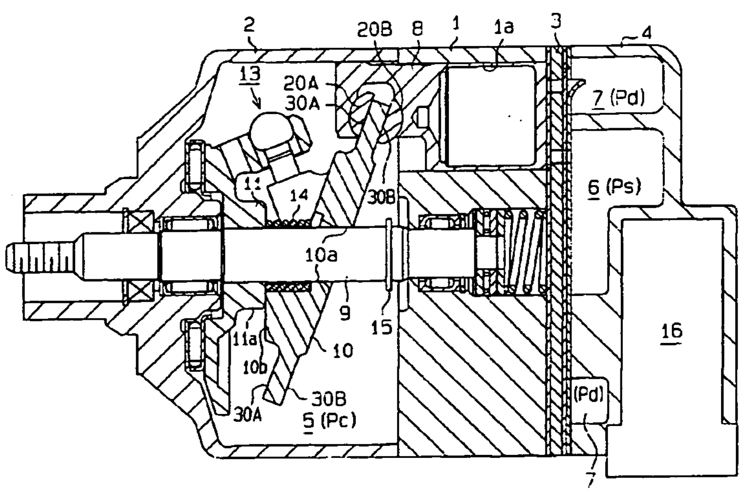
(54) Swash plate for compressor

(57) The swash plate (10) of a compressor is coated on both surfaces, the skirt side contact surface (30A) receives the skirt side shoes (20A), and the opposite head side contact surface (30B) receives the head side shoes (20B). The coating applied on the skirt side contact surface is molybdenum disulphide, tungsten disulphide, graphite, boron nitride, antimony oxide, lead oxide, indium, tin or fluorocarbon resin applied by spray coating, roll coating or screen printing processes. The coating applied on the head side contact surface consists of two layers. The first layer (31B-1) consists of aluminium silicon alloy. The second layer (31B-2) applied on the first layer consists of a solid lubricant similar to the coating of the skirt side contact surface. Additionally, the head side contact surface may be roughened by shot blasting.

Fig.1



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Description

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a swash plate that is used in a compressor, for example, in a refrigerant circuit of an air conditioner, and is coupled to single headed pistons by pairs of shoes. Each pair of the shoes has a head side shoes and a skirt side shoes. The head side shoes contacts a head side face of the swash plate, or the face that is closer to the piston heads. The skirt side shoes contacts the other side of the swash plate, or the skirt side face, which is closer to the end of the piston skirts.

[0002] The shoes and the swash plate in a swash plate type compressor are lubricated by lubricant oil retained in the compressor. Specifically, the lubricant oil is converted into mist by gas circulating in the compressor. The oil mist is then supplied to the joint between the shoes and the swash plate.

[0003] However, if the compressor is de-activated for a relatively long time, the lubricant oil that has been applied to the joint between the shoes and the swash plate is removed by refrigerant gas when the compressor is re-started. Thus, when the compressor is re-started, the lubrication between the shoes and the swash plate is insufficient until refrigerant returns to the compressor and convert the lubricant oil into mist.

[0004] Accordingly, to ensure minimum lubrication even when the lubricant supply is insufficient, various procedures for coating part of a swash plate that contacts shoes have been proposed.

[0005] Load applied to the head side face of a swash plate by the head side shoes is different from load applied to the skirt side face of the swash plate by the skirt side shoes. That is, when gas is drawn into the associated cylinder bore, the piston is pulled outward by the swash plate and the reaction force of the suction mainly acts on the skirt side face of the swash plate. When the gas is compressed in each cylinder bore, the associated piston is pressed into the cylinder bore and the reaction force of the compression mainly acts on the head side face of the swash plate. The load based on the compression reaction force is generally greater than the load based on the suction reaction force.

[0006] Therefore, the head side face, which contacts the head side shoess, need to have relatively high wear resistance. On the other hand, even if the wear resistance of the skirt side face, which contacts the skirt side shoess, is not as high as the level required for the head side face, the lubrication between the skirt side face and the skirt side shoess is maintained for an extended period.

[0007] Since the difference of the load acting on both sides of a swash plates has never been considered in prior art, the skirt side face is treated to have the same coating as that of the head side face. In other words, the skirt side face has been given an excessive wear resistance, which increases the cost for coating the swash plate.

SUMMARY OF THE INVENTION

[0008] Accordingly, it is an objective of the present invention to provide a swash plate the head and skirt side faces of which are appropriately coated for reduced cost such that necessary reliability is obtained.

[0009] To achieve the foregoing and other objectives and in accordance with the purpose of the present invention, a swash plate used in a compressor is provided. The swash plate is mounted on a drive shaft and coupled to a single-headed piston to convert a rotational movement of the drive shaft to a linearly reciprocal movement of the piston. The piston has a head portion compressing gas and receiving reaction force from the gas and a skirt portion accommodating a first shoe and a second shoe opposed to each other. The first shoe is disposed closer to the piston head than the second shoe. The first shoe and the second shoe are respectively kept in a slidable contact with a first contact surface and a second contact surface opposed to each other in the swash plate. The swash plate includes a first coating formed on the first contact surface. The first coating is made of an aluminum based material. The swash plate also includes a second coating formed on the second contact surface. The second coating material is made of a material simpler for production than the aluminum based material.

[0010] Other aspects and advantages of the invention will become apparent from the following description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The invention, together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

Fig. 1 is a cross-sectional view illustrating a swash plate type variable displacement compressor according to a first embodiment of the present invention;

Fig. 2 is a partial cross-sectional view illustrating the swash plate and a pair of the shoes of the compressor shown in Fig. 1;

Fig. 3 is a rear view showing the swash plate of the compressor shown in Fig. 1, with a metal supplier shown in perspective;

Fig. 4 is a view schematically showing a coating apparatus of the first embodiment; and

Fig. 5 is a view schematically showing a coating apparatus of a second embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0012] First and second embodiments of the present invention will now be described with reference to the attached drawings. In describing the second embodiment, only the differences from the first embodiment will be discussed. Same or like reference numerals are given to parts in the second embodiment that are the same as or like corresponding parts of the first embodiment.

[0013] First, the compressor will be described.

[0014] As shown in Fig. 1, the compressor includes a cylinder block 1, a front housing member 2, a valve plate 3, and a rear housing member 4. The front housing member 2 is coupled to a front end of the cylinder block 1. The front end is to the left in Fig. 1. The rear housing member 4 is connected to the rear end of the cylinder block 1 through the valve plate 3. The cylinder block 1, the front housing member 2, the valve plate 3, and the rear housing member 4 are fastened together with through bolts (not shown) to define a compressor housing.

[0015] A crank chamber 5, a suction chamber 6 and a discharge chamber 7 are defined in the housing. Cylinder bores la (only one is shown in Fig. 1) are defined in the cylinder block 1. A single-headed piston 8 is reciprocally accommodated in each cylinder bore la. To reduce the weight, each piston 8 is made of aluminum based material. Valve flaps are provided in the valve plate 3 for selectively connecting the suction chamber 6 and the discharge chamber 7 with each cylinder bore la.

[0016] A drive shaft 9 is rotationally supported in the crank chamber 5. A swash plate 10 is fitted around the drive shaft 9. A through hole 10a extends in the middle of the swash plate 10. The drive shaft 9 extends through the through hole 10a. The swash plate 10 is connected with the drive shaft 9 through a hinge mechanism 13 and a lug plate 11 to rotate integrally with the drive shaft 9. The swash plate 10 inclines with respect to the drive shaft 9 while axially sliding along the surface of the drive shaft 9. The skirt of each piston 8 is connected with the swash plate 10 by a skirt side shoe 20A and a head side shoe 20B. The shoes 20A, 20B slide along the periphery of the swash plate 10.

[0017] When the swash plate 10 rotates integrally with the drive shaft 9 while inclined with respect to the drive shaft 9, each piston 8 moves in the associated cylinder bore la by a stroke corresponding to the inclination angle. Refrigerant gas is drawn from the suction chamber 6 (the zone in which suction pressure Ps acts) to the cylinder bore la. The gas is then compressed in the cylinder bore la and is discharged to the discharge chamber 7 (the zone in which discharge pressure Pd acts). This series of steps is repeated.

[0018] A spring 14 urges the swash plate 10 toward the cylinder block 1 (to decrease the inclination of the swash plate 10). A snap ring 15 is secured to the drive shaft 9 for determining the minimum angle of inclination θmin (for example, three to five degrees) of the swash plate 10. A counterweight 10b is provided on the swash plate 10. The counterweight 10b abuts against a restricting portion lla of the lug plate 11. This determines the maximum inclined angle θmax of the swash plate 10.

[0019] The inclination angle of the swash plate 10 is determined according to various moments acting on the swash plate 10. The moments include a rotational moment, which is based on the centrifugal force of the rotating swash plate 10, a spring force moment, which is based on the force of the spring 14, a moment of inertia of the piston reciprocation, and a gas pressure moment.

[0020] The gas pressure moment is generated by the force of the pressure in the cylinder bores la and the pressure in the crank chamber 5 (crank pressure Pc). Depending on the crank pressure Pc, the gas pressure moment acts either to increase or decrease the inclination angle of the swash plate 10. The swash plate type compressor of Fig. 1 has a control valve 16 that adjusts the crank pressure Pc to alter the moment of the gas pressure as necessary. The control valve 16 thus selects the inclination angle of the swash plate 10 within a range between the minimum angle of inclination θmin and the maximum angle of inclination θmax.

[0021] The swash plate 10 will now be described.

[0022] As shown in Figs. 1 to 3, an annular skirt side contact surface 30A is formed on a side of the swash plate 10 that is closer to the ends of the piston skirts, and an annular head side contact surface 30B is formed on a side of the swash plate that is closer to the piston head. The skirt side shoes 20A slide on the skirt side contact surface 30A, and the head side shoes 20B slide the head side contact surface 30B.

[0023] The swash plate 10 is formed of relatively heavy, iron-based material (for example, cast iron FCD700) to optimize the moment of rotation due to centrifugal force caused by rotation of the swash plate 10. The shoes 20A, 20B are also formed of iron-based material (bearing steel) to increase their mechanical strength. If two different components formed of the same material (in this case, the swash plate 10 and the shoes 20A, 20B) slide against each other under severe conditions, seizure may occur. Accordingly, in the first embodiment, skirt side coating 31A and had side coating 31B are formed at least on the associated contact surfaces 30A, 30B. The coatings 31A, 31B allow the shoes 20A, 20B to slide smoothly along the contact surfaces 30A, 30B. That is, the procedure of the present invention is performed on the contact surfaces 30A, 30B of the swash plate 10.

[0024] The skirt side coating 31A, which is formed on the skirt side contact surface 30A, is made of solid lubricant. The thickness of the skirt side coating 31A is for example 0.5 to 10μm. The solid lubricant includes at least one of molybdenum disulfide, tungsten disulfide, graphite, boron nitride, antimony oxide, lead oxide, indium, tin and fluorocarbon resin. When forming the skirt

side coating 31A, a liquid paint that includes the solid lubricant is applied to the skirt side contact surface 30A through spray coating, roll coating or screen printing.

[0025] The head side coating 31B, which is formed on the head side contact surface 30B, has a two-layer structure. A first layer 31B-1 of the head side coating 31B is formed of metal different from that forming the body of the swash plate 10 and the bodies of the shoes 20A, 20B. The material of the first layer 31B-1 may be Al-Si based material including, for example, silicon containing aluminum alloys and intermetallic compounds consisting of aluminum and silicon. The physical properties such as hardness and melting point of the Al-Si based material, or aluminum based material, vary in accordance with the silicon content of the material. In the first embodiment, the Al-Si based material contains 10 to 20 weight percent (preferably, from 15 to 18 percent) silicon.

[0026] A second layer 31B-2 of the head side coating 31B covers the first layer 31B-1. Like the skirt side coating 31A, the second layer 31B-2 is formed of solid lubricant and the thickness is between 0.5 and 10μm.

[0027] The coatings 31A, 31B prevent seizure from occurring between the shoes 20A, 20B and the contact surfaces 30A, 30B. The coatings 31A, 31B also allow the shoes 20A, 20B to slide smoothly along the contact surfaces 30A, 30B of the swash plate 10. In other words, even when the lubricant oil supply to the compressor is insufficient, the coatings 31A, 31B ensure a certain level of lubrication between the swash plate 10 and the shoes 20A, 20B.

[0028] A procedure for forming the coatings 31A, 31B will hereafter be described. The head side contact surface 30B is roughened through, for example, shot blasting.

[0029] As shown in Fig. 3, the procedure is performed with a cylindrical metal supplier 40. The supplier 40 is formed of Al-Si based material. The supplier 40 has a planer end 41 having a diameter substantially equal to a radial dimension of the head side contact surface 30B of the swash plate 10 (the difference between the outer radius and the inner radius of the head side contact surface 30B).

[0030] As shown in Fig. 4, the swash plate 10 is mounted to a first drive mechanism 51, and the supplier 40 is connected to a second drive mechanism 52.

[0031] The first drive mechanism 51 is driven by a first motor M1. When the first motor M1 drives the first drive mechanism 51, the swash plate 10 is rotated about an axis L. Specifically, with the swash plate 10 mounted to the first drive mechanism 51, the head side contact surface 30B is centered on the axis L and is perpendicular to axis L. In this state, a portion of the head side contact surface 30B faces and is spaced from the end 41 of the supplier 40.

[0032] The second drive mechanism 52 is operably connected to a linear mover 53 and a second motor M2. The linear mover 53 operates to move the supplier 40 axially. Specifically, the linear mover 53 enables the supplier 40 to contact the swash plate 10. The supplier 40 is then pressed against the head side contact surface 30B of the swash plate 10 by the linear mover 53. Afterwards, the linear mover 53 separates the supplier 40 from the swash plate 10. When the linear mover 53 moves the supplier 40, the second motor M2 rotates the supplier 40 about the axis L', which is the axis of the supplier 40.

[0033] The end 41 of the supplier 40 is perpendicular to the axis L'. When the supplier 40 is mounted to the second drive mechanism 52, the end 41 is parallel to the head side contact surface 30B, and the rotation axis L' of the supplier 40 is offset from axis L. That is, when the supplier 40 is pressed against the head side contact surface 30B of the swash plate 10, one point on the circumference of the end 41 touches the outer circumference of the head side contact surface 30B, and a diametrically opposite point on the end 41 touches the inner circumference of the head side contact surface 30B (as indicated by broken lines in Fig. 3).

[0034] After the swash plate 10 and the supplier 40 are mounted on the associated drive mechanisms 51, 52, the second motor M2 rotates the supplier 40 at a predetermined speed (for example, 1,500 rpm) about the axis L'. The linear mover 53 causes the supplier 40 and the second drive mechanism 52 to approach the swash plate 10. After the supplier 40 contacts the head side contact surface 30B of the swash plate 10, the supplier 40 is pressed against the head side contact surface 30B until the pressure reaches a predetermined level (for example, 18 MPa).

[0035] When the supplier 40 is pressed against the head side contact surface 30B, the first motor M1 rotates the swash plate 10 by a predetermined rotation speed (for example, 1 rpm). That is, the supplier 40 and the head side contact surface 30B move relative to each other along the circumferential direction of the head side contact surface 30B.

[0036] Heat, which is caused by friction, is generated between the end 41 of the supplier 40 and the head side contact surface 30B. The heat is mainly caused by the relatively rapid rotation of the supplier 40. The heat softens a portion of the supplier 40 near its end 41. Molten metal is then supplied from the soft portion of the supplier 40 to a corresponding portion of the head side contact surface 30B. Accordingly, while the supplier 40 is moving relative to the head side contact surface 30B, molten metal is continuously supplied from the supplier 40 to the head side contact surface 30B along the annular path of the surface 30B.

[0037] When at least one rotation cycle is completed by the swash plate 10, molten metal is supplied to the entire head side contact surface 30B. This forms the first layer 31B-1 of Al-Si based material. The thickness of the head side coating 31B is, for example, 70 to 100 micrometers. The thickness is determined by adding a finishing allowance (which is, for example, 20 to 50 mi-

crometers) to the desired coating thickness (which is, for example, 50 micrometers).

[0038] Afterwards, the surface of the first layer 31B-1 is machined through cutting or grinding to adjust the thickness of the first layer 31B-1 as desired.

[0039] The surface of the first layer 31B-1 is roughened through, for example, shot blasting. Liquid paint containing solid lubricant is applied to the roughened surface of the first layer 31B-1 in the same manner as the procedure for forming the skirt side coating 31A. Thereafter, the applied liquid paint is baked for forming the second layer 31B-2. Afterwards, the surface of the second layer 31B-2 is machined through cutting or grinding to adjust the thickness of the first layer 31B-1, or the thickness of the head side coating 31B, as desired.

[0040] The first embodiment has the following advantages.

(1) The first layer 31B-1 is formed only on the head side contact surface 30B, which need to have high wear resistance. The skirt side contact surface 30A, which need to have relatively low wear resistance, is coated with the solid lubricant skirt side coating 31A. Solid liquid is inexpensive. Therefore, the swash plate 10 has sufficient level of lubrication for a minimized cost.

(2) The first layer 31B-1 is hard and therefore is easy to crack if the first layer 31B-1 directly contacts the head side shoes 20B. However, in the first embodiment, the relatively soft second layer 31B-2 is formed on the first layer 31B-1, which prevents the first layer 31B-1 from directly contacting the head side shoes 20B. Cracking of the first layer 31B-1 is thus prevented.

(3) The head side contact surface 30B is roughened before applying the first layer 31B-1. This increases the contact area between the head side contact surface 30B and the first layer 31B-1 and thus improves the adherence.

(4) The surface of the first layer 31B-1 is roughed before applying the second layer 31B-2. This increases the contact area between the first layer 31B-1 and the second layer 31B-2 and thus improves the adherence.

(5) The first layer 31B-1 is formed on the head side contact surface 30B by pressing the metal supplier 40 against the head side contact surface 30B. Therefore, unlike thermal spraying, no spraying noise is produced. Also, metal powder is not spread, which improves yield and working conditions.

(6) Molten metal is reliably separated from the supplier 40 and is supplied to the head side contact surface 30B. That is, a predetermined amount of metal is reliably supplied from the supplier 40 to the head side contact surface 30B. The first layer 31B-1 thus has a desired uniform thickness along the entire head side contact surface 30B.

(7) The supplier 40, which is a solid metal cylinder, is pressed against the head side contact surface 30B for forming the first layer 31B-1. Therefore, unlike thermal spraying, costly metal powder is not needed. Further, metal cylinders are easier to handle than metal powder, which improves the efficiency and the working conditions.

[0041] A second embodiment will now be described with reference to Fig. 5. In the second embodiment, the first layer 31B-1 is formed through build up welding by using a coated electrode 54.

[0042] Fig. 5 schematically shows an arc welding apparatus 60. A first drive mechanism 51 of the second embodiment is installed such that the axis L is perpendicular to the axis L in the embodiment of Figs. 1 to 4. The arc welding apparatus 60 includes an electrode 54 and a welding source 55, which applies voltage to the electrode 54 and the swash plate 10. The electrode 54 is formed by applying flux 54b on a core 54a, which is made of Al-Si based material. The electrode 54 is supported by a support 56, which is connected to a lift 57.

[0043] The axis of the electrode 54 is offset from the axis L of the swash plate 10, which is placed on the first drive mechanism 51 and is located above the head side contact surface 30B. The support 56, together with the electrode 54, is moved vertically as viewed in the drawing by the lift 57, which permits the electrode 54 to approach and separate from a part of the head side contact surface 30B.

[0044] When the lift 57 lowers the electrode 54 toward a part of the head side contact surface 30B and the welding source 55 is activated, arc is generated between the electrode 54 and the swash plate 10. The heat of the arc melts part of the electrode core 54a. Molten metal is dropped onto the contact surface. The molten part of the electrode 54 is fused with part of the head side contact surface 30B, which is also molten by the arc heat. The motor M1 rotates the first drive mechanism 51 with the swash plate 10, which continuously changes part of the head side contact surface 30B that is located below the electrode 54.

[0045] When at least one rotation cycle is completed by the swash plate 10, molten metal is supplied to the entire head side contact surface 30B. This forms the first layer 31B-1 of Al-Si based material.

[0046] The second embodiment has the advantages (1)-(5) and (7) of the first embodiment.

[0047] It should be apparent to those skilled in the art that the present invention may be embodied in many other specific forms without departing from the spirit or

scope of the invention. Particularly, it should be understood that the invention may be embodied in the following forms.

[0048] The first layer 31B-1 may be formed through thermal spraying. In thermal spraying, metal powder is molten and sprayed on to the head side contact surface 30B with flame.

[0049] The first layer 31B-1 may be formed through sintering. In sintering, metal powder is sintered on to the head side contact surface 30B with flame.

[0050] The skirt side coating 31A may be formed of tin through electroplating or through electroless plating.

[0051] In the second embodiment, the first layer 31B-1 is formed through arc welding by using the coated electrode 54. However, the first layer 31B-1 may be formed through gas-shielded arc welding or submerged-arc welding. Gas-shielded arc welding includes metal inert gas (MIG) welding, metal active gas (MAG) welding and TIG welding.

[0052] The procedures of the present invention may be applied to swash plates 10 formed of aluminum based material instead of iron based material.

[0053] Therefore, the present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein, but may be modified within the scope and equivalence of the appended claims.

[0054] A swash plate used in a compressor. A side of the swash plate that contacts head side shoes is coated with two layers. The first layer is formed of aluminum material and the second layer is formed with solid lubricant. A side of the swash plate that contacts skirt side shoes is coated with a single layer of solid lubricant. Accordingly, the swash plate has a sufficiently wear resistance on both sides for the minimized cost.

Claims

1. A swash plate used in a compressor, the swash plate is mounted on a drive shaft and coupled to a single-head piston to convert a rotational movement of the drive shaft to a linearly reciprocal movement of the piston, the piston having a head portion compressing gas and receiving reaction force from the gas and a skirt portion accommodating a first shoe and a second shoe opposed to each other, the first shoe being disposed closer to the piston head than the second shoe, the first shoe and the second shoe being respectively kept in a slidable contact with a first contact surface and a second contact surface opposed to each other in the swash plate, the swash plate comprising:

   a first coating formed on the first contact surface, the first coating being made of an aluminum based material; and
   a second coating formed on the second contact surface, the second coating material being made of a material simpler for production than the aluminum based material.

2. The swash plate as set forth in Claim 1, wherein the second coating is made of one of a rigid lubrication layer, a plating layer and a sinter.

3. The swash plate as set forth in Claim 1, wherein the first coating is formed on the first contact surface by one selected from a group consisting of a pressure welding, a welding and a flame spraying.

4. The swash plate as set forth in Claim 1, wherein the first contact surface is finished by roughening.

5. The swash plate as set forth in Claim 1, wherein the first coating is coated by a rigid lubrication layer.

6. The swash plate as set forth in Claim 5, wherein the first coating has a roughened surface.

7. The swash plate as set forth in Claim 1, wherein the first coating is made of an aluminum alloy containing silicon.

8. The swash plate as set forth in Claim 1, wherein the first coating includes a first layer made of an aluminum alloy containing silicon and a second layer formed on the first layer and made of a rigid lubrication agent.

9. The swash plate as set forth in Claim 8, wherein the first layer is formed of the aluminum alloy containing 10 to 20 weight percent of the silicon.

Fig.1

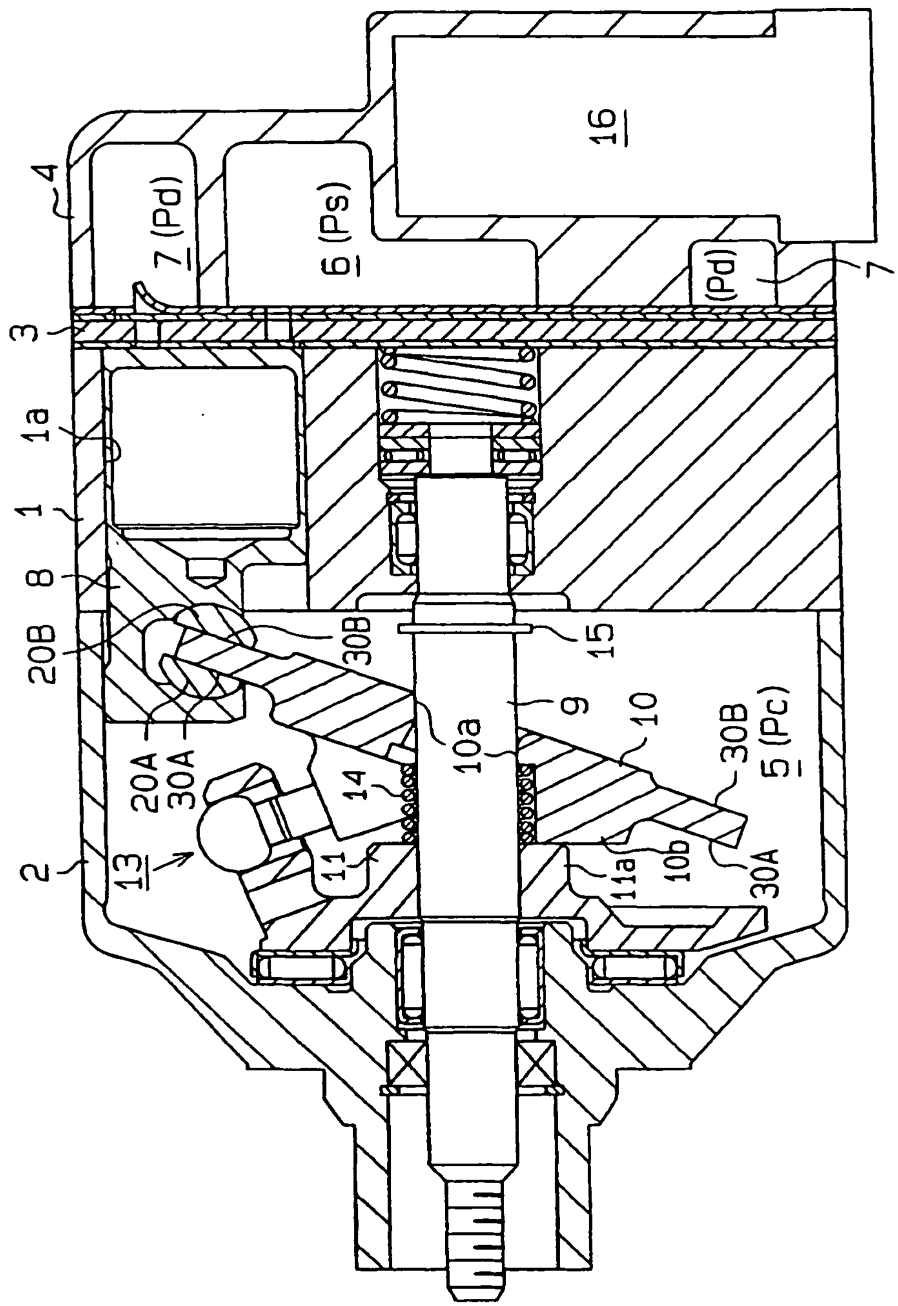
4
7 (Pd)
6 (Ps)
16
(Pd)
7
3
1a
1
8
20B
30B
15
9
10
10a
20A
30A
14
11
11a
10b
30A
30B
5 (Pc)
2
13

Fig.2

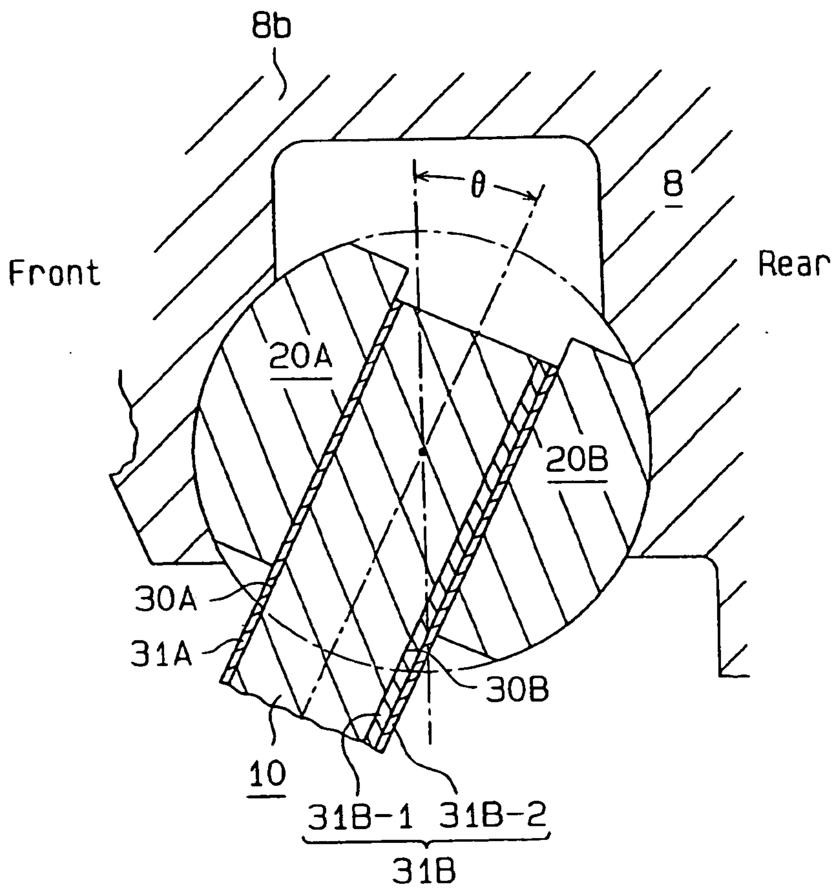

Fig.3

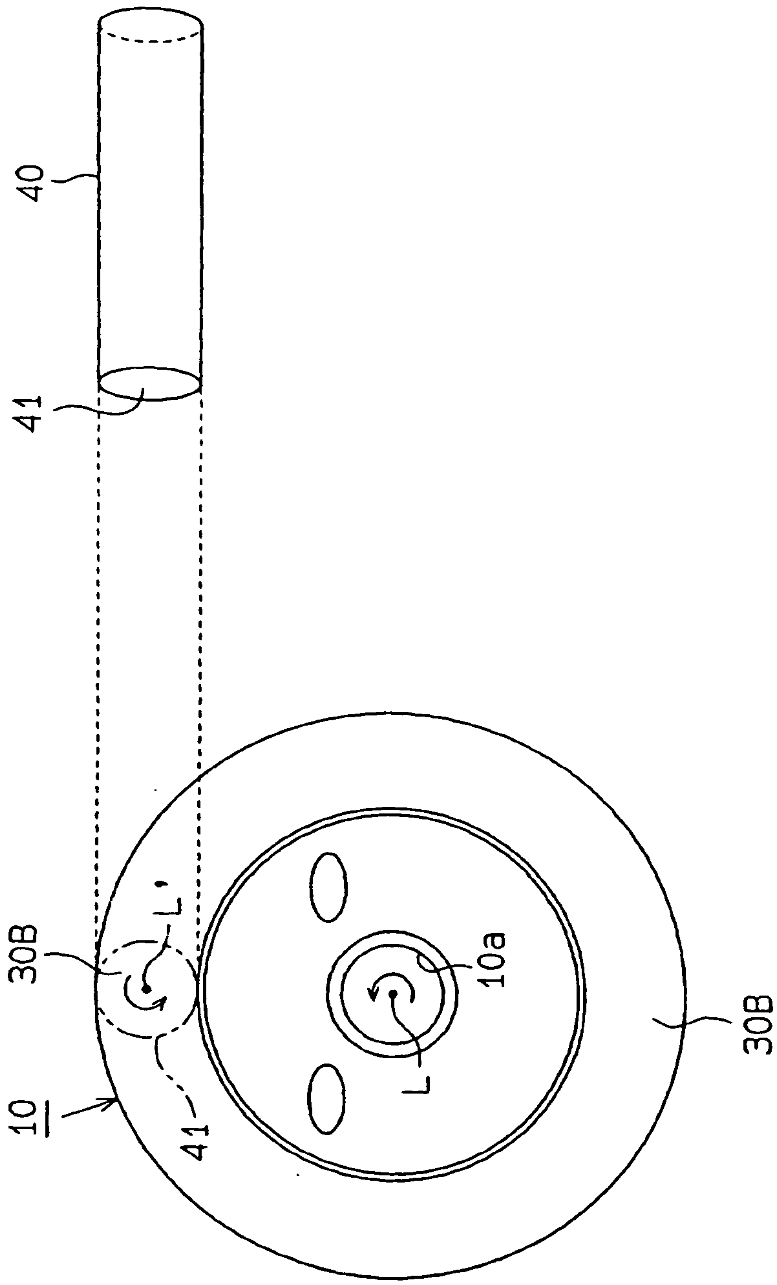

Fig.4

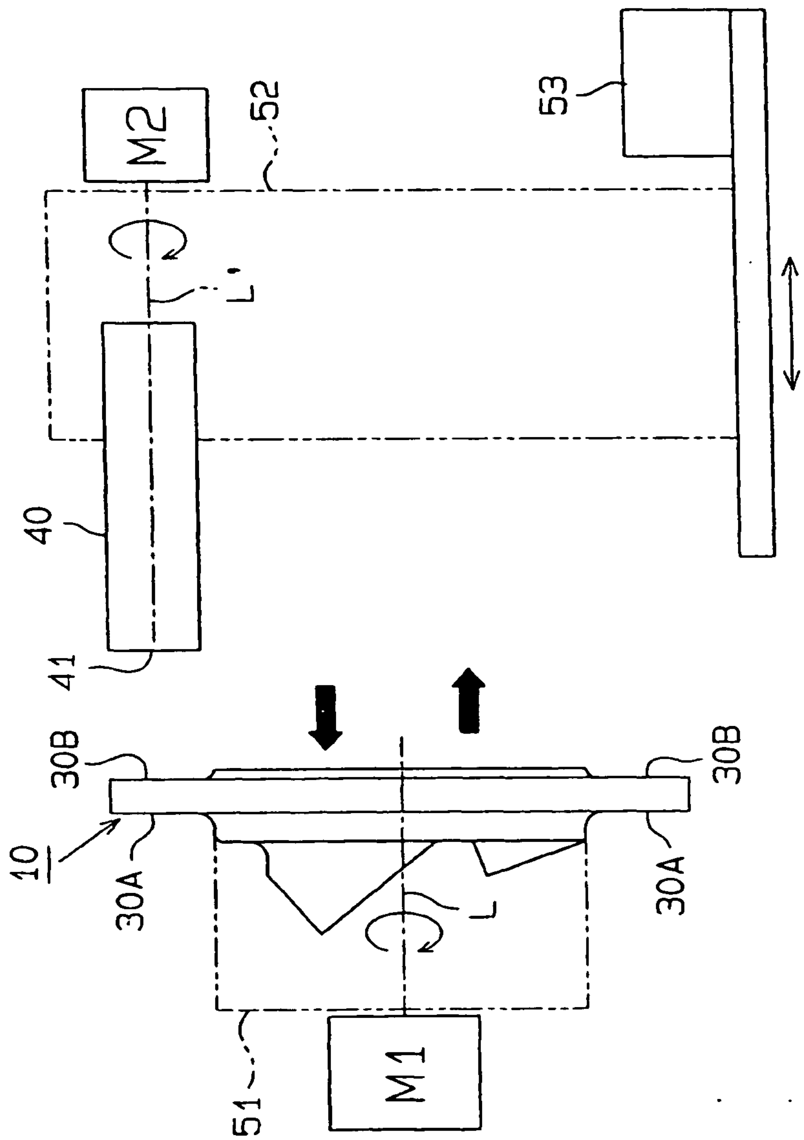

Fig.5